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DEMANDE DE BREVET D'INVENTION

(21) **N° 78 32499**

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(54) **Fibre optique.**

(51) Classification internationale. (Int. Cl 3) G 02 B 5/14.

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(71) Déposant : COMPAGNIE GENERALE D'ELECTRICITE. Société anonyme, résidant en France.

(72) Invention de : Jean-Yves Boniort, Claude Brehm, Jean-Pierre Dumas et Philippe Dupont.

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(74) Mandataire : Christian Lheureux.

La présente invention concerne une fibre optique.

On connait une fibre optique, dite à échelon d'indice, comportant un coeur cylindrique en verre entouré d'une gaine tubulaire constituée d'un matériau dont l'indice de réfraction est inférieur à celui du coeur. Lorsque le diamètre du coeur de la fibre est relativement grand, par exemple de l'ordre de 100 microns, la fibre peut transmettre un rayonnement lumineux multimode. Associée à une diode électroluminescente ou à un laser à semi-conducteur émettant un rayonnement de longueur d'onde comprise entre 800 et 900 nanomètres, une fibre optique de ce type peut être appliquée à un dispositif de transmission d'informations à distance.

Bien que le débit d'informations des dispositifs utilisant un rayonnement multimode soit relativement faible (de l'ordre de 50 mégabits par seconde), ces dispositifs présentent à l'heure actuelle un intérêt économique important. En effet, les émetteurs associés à ces dispositifs sont très fiables.

Pour réaliser une fibre optique capable de transmettre un rayonnement monomode, il est nécessaire d'utiliser une fibre optique dont le diamètre du coeur est beaucoup plus faible, de l'ordre de 3 à 6 microns. Ces fibres sont capables de transmettre des débits d'informations beaucoup plus importants, par exemple de plusieurs gigabits par seconde, mais elles doivent pour cela être associées à des émetteurs laser présentant une cohérence élevée, ces émetteurs étant beaucoup moins fiables que les diodes électroluminescentes ou les lasers à semi-conducteurs. De plus, le raccordement optique entre l'émetteur et la fibre pose des problèmes techniques difficiles à cause du faible diamètre du coeur de la fibre. On prévoit que dans l'avenir les problèmes de fiabilité des lasers et de raccordement seront résolus, ce qui permettra de profiter des grands débits d'informations des fibres optiques transmettant un rayonnement monomode.

Dans l'état actuel de la technique, les dispositifs de transmission par voie optique doivent nécessairement utiliser un rayonnement multimode. En fait, la réalisation de tels dispositifs peut difficilement être envisagée lorsque les informations doivent être transmises sur une longue distance. En effet, l'installation de la fibre elle-même exige des investissements importants qui seraient à renouveler lorsque les dispositifs de transmission utilisant des rayonnements monomodes seront opérationnels.

La présente invention a pour but de pallier cet inconvénient et de réaliser une fibre optique capable de transmettre un rayonnement multimode ou un rayonnement monomode.

La présente invention a pour objet une fibre optique comportant
- un coeur cylindrique

- et une gaine tubulaire coaxiale d'indice de réfraction n_3, cette gaine entourant immédiatement le coeur, la fibre optique étant capable de transmettre dans le coeur un rayonnement lumineux multimode de longueur d'onde L, caractérisée en ce que le coeur est constitué

- d'une première partie cylindrique coaxiale, d'indice de réfraction n_1

- et d'une deuxième partie tubulaire coaxiale entourant immédiatement la première partie, cette deuxième partie ayant un indice de réfraction n_2 inférieur à n_1 mais supérieur à n_3,

la valeur du diamètre de ladite première partie étant suffisamment faible pour que la fibre optique soit capable de transmettre dans cette première partie un rayonnement lumineux monomode de longueur d'onde sensiblement égale à L, lorsque le rayonnement lumineux multimode n'est pas transmis.

Des formes particulières de l'objet de la présente invention sont décrites ci-dessous, à titre d'exemple, en référence au dessin annexé comportant une figure unique représentant en coupe transversale un mode de réalisation de la fibre optique selon l'invention.

La fibre représentée sur cette figure comporte un coeur cylindrique en verre de diamètre d_2. Ce coeur est composé de deux parties, une partie 1 cylindrique de diamètre d_1 et d'indice de réfraction n_1 et une partie 2 tubulaire coaxiale. La partie 2 entoure immédiatement la partie 1 : il en résulte que son diamètre intérieur est égal à d_1, son diamètre extérieur étant égal au diamètre d_2 du coeur de la fibre. L'indice de réfraction n_2 du verre constituant la partie 2 est inférieur à n_1.

La fibre optique comporte enfin une gaine tubulaire 3, de diamètre extérieur d_3, entourant immédiatement la partie 2 du coeur : son diamètre intérieur est donc d_2. La gaine 3 peut être constituée soit d'un verre soit comme représenté d'une matière plastique transparente telle qu'une résine silicone. Le matériau constituant la gaine 3 a un indice de réfraction n_3 inférieur à n_2.

La fibre représentée sur la figure peut transmettre dans le coeur de diamètre d_2 un rayonnement lumineux multimode de longueur d'onde moyenne L. Pour cela, le diamètre d_2 doit être choisi pour que la relation

$$\frac{d_2}{2L} > 0,383 \ (n_2^2 - n_3^2)^{-\frac{1}{2}} \qquad (1)$$

soit satisfaite.

A titre indicatif, on peut avoir par exemple :

d_2 = 55 microns

L = 0,830 micron

$n_3 = 1,45$

$n_2 = 1,505$

et $d_3 = 140$ microns

On remarquera que l'inégalité 1 a été écrite en prenant n_2 comme indice de réfraction de coeur, alors que le coeur est composé de deux parties d'indices respectifs n_1 et n_2. En fait cette approximation est légitime car la section de la première partie 1 du coeur est toujours faible par rapport à la section totale du coeur et l'indice de réfraction de cette première partie est très proche de celui de la deuxième partie.

A titre indicatif, on a :

$d_1 = 5$ microns

$n_1 = 1,51$.

La fibre optique représentée sur la figure peut aussi transmettre un rayonnement lumineux monomode de longueur d'onde sensiblement égale à L, lorsqu'elle ne transmet pas le rayonnement multimode.

Le rayonnement monomode est alors transmis par la première partie 1, de faible diamètre, du coeur de la fibre. La valeur du diamètre d_1 de la première partie 1 du coeur doit être suffisamment faible pour que soit satisfaite l'inégalité suivante

$$\frac{d_1}{2L} < 0,383 \quad (n_1^2 - n_2^2)^{-\frac{1}{2}} \qquad (2)$$

qui n'est autre que la condition bien connue de transmission d'un rayonnement monomode.

La fibre décrite ci-dessus a un diamètre extérieur plus grand que le diamètre extérieur strictement nécessaire pour assurer la transmission du rayonnement monomode. Ce diamètre relativement grand de la fibre est en réalité un avantage car il facilite les manipulations et permet d'éviter des ruptures.

Par ailleurs la partie 2 de la fibre qui se comporte comme une gaine dans le fonctionnement en régime monomode doit être formée d'un verre à faible atténuation pour assurer un bon fonctionnement en régime multimode. En régime monomode, la faible atténuation de cette partie 2 permet de diminuer les pertes optiques non négligeables qu'on observe généralement dans les gaines de fibres optiques transmettant un rayonnement monomode.

Lorsque la gaine 3 est en verre, la fibre optique selon l'invention peut être obtenue par tirage à chaud d'une ébauche. L'ébauche peut être réalisée en utilisant la méthode connue de dépôt en phase vapeur ou par introduction d'un barreau dans un tube lui-même situé dans le volume interne d'un autre tube concentrique.

Lorsque la gaine 3 est en matière plastique, la fibre selon l'invention peut être obtenue, par une méthode d'enduction également connue, à partir d'une fibre optique à échelon d'indice.

Une fibre selon l'invention peut être appliquée à la transmission d'informations par rayonnement optique multimode. Pour cela, on dirige le rayonnement d'une source à faible cohérence sur les parties 1 et 2 d'une section extrême de la fibre.

Une telle fibre peut être aussi appliquée à la transmission d'informations par rayonnement optique monomode. Pour cela, on dirige alors le rayonnement d'une source laser à grande cohérence sur la partie 1 de la section extrême de la fibre.

Il en résulte qu'une même fibre selon l'invention peut être d'abord utilisée dans un dispositif de transmission d'informations par rayonnement multimode, ce dispositif multimode pouvant être ensuite transformé en un dispositif monomode par changement de la source de rayonnement, mais sans changement de la fibre elle-même.

Bien entendu la présente invention n'est nullement limitée aux modes de réalisation décrits et représentés qui n'ont été donnés qu'à titre d'exemple. En particulier, on peut, sans sortir du cadre de l'invention changer certaines dispositions et remplacer certains moyens par des moyens équivalents.

REVENDICATIONS

1/ Fibre optique comportant

- un coeur cylindrique

- et une gaine tubulaire coaxiale d'indice de réfraction n_3, cette gaine entourant immédiatement le coeur, la fibre optique étant capable de transmettre dans le coeur un rayonnement lumineux multimode de longueur d'onde L, caractérisée en ce que le coeur est constitué

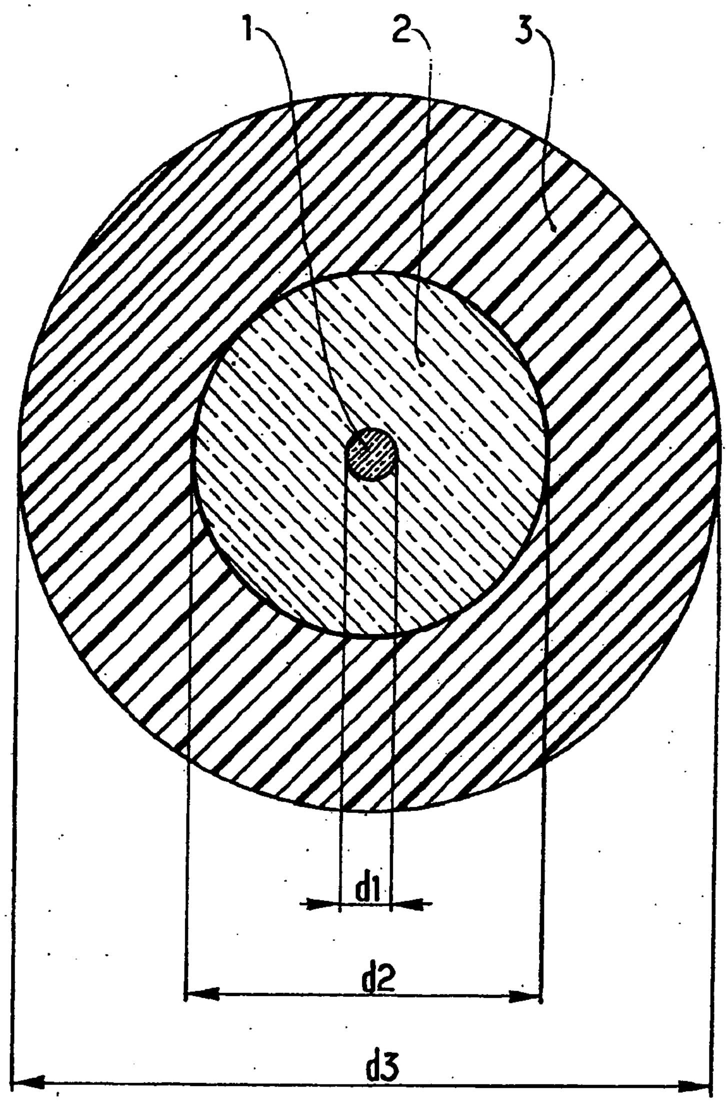
- d'une première partie cylindrique d'indice de réfraction n_1

- et d'une deuxième partie tubulaire coaxiale entourant immédiatement la première partie, cette deuxième partie ayant un indice de réfraction n_2 inférieur à n_1 mais supérieur à n_3,

la valeur du diamètre de ladite première partie étant suffisamment faible pour que la fibre optique soit capable de transmettre dans cette première partie un rayonnement lumineux monomode de longueur d'onde sensiblement égale à L, lorsque le rayonnement lumineux multimode n'est pas transmis.

2/ Fibre optique selon la revendication 1, caractérisée en ce que la gaine est constituée d'une matière plastique transparente.

3/ Fibre optique selon la revendication 1, caractérisée en ce que la gaine est constituée d'un verre.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This is to certify that the foregoing translation of patent **FR2 441 858** was made from French to English by a competent translator well acquainted with both languages, and that, to the best of our knowledge and belief, it is a true and complete rendering into English of the original document.

7/5/06.
Donald W. Hanley, CEO

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PATENT APPLICATION

(21) N° 78 32499

(54) **Optical fiber.**

(51) International classification: (Int. Cl 3) G 02 B 5/14.

(22) Filling date............... November 17, 1978, at 14:55.

(33)(32)(31) Priority claimed:

(41) Date of publication of the application: B.O.P.I. - «Lists » n. 24 of 6-13-1980.

(71) Applicant: COMPAGNIE GENERALE D'ELECTRICITE. public limited company, residing in France.

(72) Invention of: Jean-Yves Boniort, Claude Brehm, Jean-Pierre Dumas, and Philippe Dupont.

(73) Holder: Idem (71)

(74) Attorney: Christian Lheureux.

The present invention concerns an optical fiber.

An optical fiber is known, with a so-called step index, which comprises a cylindrical glass core surrounded by a tubular cover that consists of a material that has a refraction index that is lower than that of the core. As the diameter of the core of the fiber is relatively large, e.g, 100 microns, the fiber can transmit multimode optical radiation. Combined with an electro-luminescent diode or a laser with a semiconductor that emits radiation with a wavelength between 800 and 900 nanometers, an optical fiber of this type can be applied to a device for information transmission over a distance.

Although the information rates of devices that use multimode radiation is relatively low (50 megabits per second), today these devices offer an important economical advantage. In fact, the emitters associated with these devices are very reliable.

It is necessary to use an optical fiber of which the diameter of the core is a lot smaller, appproximately 3 to 6 microns, in order to realize an optical fiber that is capable of transmitting monomode radiation. These fibers are capable of transmitting information at much more significant rates, for example, of several gigabits per second, but for this, they must be combined with laser emitters that produce an increased coherence, these emitters being much less reliable than the electro-luminescent diodes or the lasers with semiconductors. Moreover, the optical joining of the emitter and the fiber poses difficult technical problems because of the small diameter of the core of the fiber. One expects that the problems of the reliability of the lasers and the joining will be resolved in the future, so that it will be possible to take advantage of the large information rates of optical fibers that transmit monomode radiation.

It is unavoidable that the optical transmission devices of the present state of the art must utilize multimode radiation. Actually, the realization of such devices can be envisaged only with difficulty when the information must be transmitted over a long distance. In fact, the installation of the fiber itself requires considerable investments that will recur when the transmission devices that utilize monomode radiation will become operational.

The present invention has the goal to remedy this inconvenience and to realize an optical fiber that is capable of transmitting multimode radiation or monomode radiation.

The present invention has as object an optical fiber comprising:

- a cylindrical core

- and a coaxial tubular cover with a refraction index n_3, this cover immediately surrounds the core, the optical fiber being capable of transmitting in the core multimode optical radiation with wavelength L, characterized by that this core is formed by
- a first coaxial cylindrical part with refraction index n_1
- and a second coaxial tubular part that immediately surrounds the first part, while this second part has a refraction index n_2 that is lower than n_1 but larger than n_3,

the value of the diameter of the said first part is sufficiently low so that the optical fiber is capable of transmitting in the first part monomode optical radiation with a wavelength that is approximately equal to L, when the optical multimode radiation is not transmitted.

Particular forms of the object of the present invention are described below, as an example, with reference to the appended drawing which comprises only one figure that represents in cross section a realization mode of the optical fiber according to the invention.

The fiber represented in this figure contains a cylindrical glass core of diameter d_2. This core consists of two parts, a cylindrical part 1 with diameter d_1 and a refraction index n_1 and a second coaxial tubular part 2. Part 2 immediately surrounds part 1: as a result, its internal diameter is equal to d_1 and its external diameter is equal to the diameter d_2 of the core of the fiber. The refraction index n_2 of the glass that forms part 2 is smaller than n_1.

Finally, the optical fiber comprises a tubular cover 3, with external diameter d_3, that immediately surrounds part 2 of the core: Its internal diameter is thus d_2. The cover 3 can be made either of a glass or, as represented, a transparent plastic such as a silicon resin. The material that forms the cover 3 has a refraction index n_3 which is smaller that n_2.

The in the figure represented fiber can transmit in the core of diameter d_2 multimode optical radiation with an average wavelength L. Hereto the diameter d_2 must be chosen in such a way that the relation:

$$\frac{d}{2L} > 0.383 \, {}^{b} n_2^2 @ n_3^2 \, {}^{c@_2} \qquad (1),$$

is satisfied.

As an indication, one could choose, for example:

d_2 = 55 microns

L = 0.830 microns

$n_3 = 1.45$

$n_2 = 1.505$
and, $d_3 = 140$ microns.

One will notice that inequality 1 is written using n_2 for the refraction index of the core while the core is composed of two parts with indices n_1 and n_2, respectively. In fact, this approximation is valid because the section of the first part 1 is always small with respect to the total section of the core and the refraction index of this first part is very close to that of the second part.

As an example, one has:
$d_1 = 5$ microns
$n_1 = 1.51$.

The in the figure represented optical fiber can also transmit monomode optical radiation, with a wavelength approximately equal to L, when it does not transmit the multimode radiation.

The monomode radiation is thus transmitted in the first part 1, with a smaller diameter, of the core of the fiber. The value of the diameter d_1 of the first part 1 of the core must be sufficiently small so that the following inequality:

$$\frac{d_1}{2L} < 0.383\left(n_1^2 - n_2^2\right)^{-\frac{1}{2}} \qquad (2),$$

which is nothing but the well-known condition for the transmission of monomode radiation, is satisfied.

The fiber described in the above has an external diameter that is much larger than the external diameter and this is strictly necessary in order to ensure transmission of monomode radiation. This relatively large diameter of the fiber is in reality an advantage because it facilitates handling and makes it possible to avoid breaking.

Moreover, part 2 of the fiber, which behaves as a cover when operating in the monomode regime, must be made from glass with a low attenuation in order to ensure good functioning in the multimode regime. In the monomode regime, the low attenuation of this second part 2 allows a significant reduction of the optical losses which one generally observes in the covers of optical fibers that transmit monomode radiation.

The optical fiber according to the invention can be obtained by pulling a warm optical blank if the cover 3 is made from glass. The optical blank can be realized by utilizing the known vapor deposit method or by the introduction of a bar in a tube that is itself located in the internal volume of another concentric tube.

If the cover 3 is made from plastic, the fiber according to the invention can be obtained, starting from an optical fiber with step index, by a coating method that is also known.

A fiber according to the invention can be applied to the transmission of information using multimode optical radiation. For this, one directs the radiation of a source with low coherence to the parts 1 and 2 of an end section of the fiber.

Such a fiber can also be applied for the transmission of information with monomode optical radiation. For this, one directs the radiation of a laser source with high coherence to the part 1 of the end section of the fiber.

As a result, the same fiber according to the invention can be used initially in a transmission device for information using multimode radiation and later this multimode device could be transformed into a monomode device by changing the radiation source, but without changing the fiber itself.

Of course, the present invention is not at all limited to the realization modes described and represented, which were only given as indications of examples. In particular, one can, without leaving the framework of the invention, change certain arrangements and replace certain means with equivalent means.

CLAIMS

1. Optical fiber comprising:
- a cylindrical core
- and a coaxial tubular cover with a refraction index n_3, this cover immediately surrounds the core, the optical fiber being capable of transmitting in the core multimode optical radiation with wavelength L, characterized by that this core is formed by
- a first coaxial cylindrical part with refraction index n_1.
- and a second coaxial tubular part that immediately surrounds the first part, while this second part has a refraction index n_2 that is lower than n_1 but larger than n_3,

the value of the diameter of the said first part is sufficiently low so that the optical fiber is capable of transmitting in the first part monomode optical radiation, with a wavelength approximately equal to L, when the optical multimode radiation is not transmitted.

2. Optical fiber according to claim 1, characterized by that the cover consists of a transparent plastic.

3. Optical fiber according to claim 1, characterized by that the cover consists of a glass.

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Although the information rates of devices that use multimode radiation is relatively low (50 megabits per second), today these devices offer an important economical advantage. In fact, the emitters associated with these devices are very reliable.

It is necessary to use an optical fiber of which the diameter of the core is a lot smaller, appproximately 3 to 6 microns, in order to realize an optical fiber that is capable of transmitting monomode radiation. These fibers are capable of transmitting information at much more significant rates, for example, of several gigabits per second, but for this, they must be combined with laser emitters that produce an increased coherence, these emitters being much less reliable than the electro-luminescent diodes or the lasers with semiconductors. Moreover, the optical joining of the emitter and the fiber poses difficult technical problems because of the small diameter of the core of the fiber. One expects that the problems of the reliability of the lasers and the joining will be resolved in the future, so that it will be possible to take advantage of the large information rates of optical fibers that transmit monomode radiation.

It is unavoidable that the optical transmission devices of the present state of the art must utilize multimode radiation. Actually, the realization of such devices can be envisaged only with difficulty when the information must be transmitted over a long distance. In fact, the installation of the fiber itself requires considerable investments that will recur when the transmission devices that utilize monomode radiation will become operational.

The present invention has the goal to remedy this inconvenience and to realize an optical fiber that is capable of transmitting multimode radiation or monomode radiation.

The present invention has as object an optical fiber comprising:

- a cylindrical core

- and a coaxial tubular cover with a refraction index n_3, this cover immediately surrounds the core, the optical fiber being capable of transmitting in the core multimode optical radiation with wavelength L, characterized by that this core is formed by
- a first coaxial cylindrical part with refraction index n_1
- and a second coaxial tubular part that immediately surrounds the first part, while this second part has a refraction index n_2 that is lower than n_1 but larger than n_3,

the value of the diameter of the said first part is sufficiently low so that the optical fiber is capable of transmitting in the first part monomode optical radiation with a wavelength that is approximately equal to L, when the optical multimode radiation is not transmitted.

Particular forms of the object of the present invention are described below, as an example, with reference to the appended drawing which comprises only one figure that represents in cross section a realization mode of the optical fiber according to the invention.

The fiber represented in this figure contains a cylindrical glass core of diameter d_2. This core consists of two parts, a cylindrical part 1 with diameter d_1 and a refraction index n_1 and a second coaxial tubular part 2. Part 2 immediately surrounds part 1: as a result, its internal diameter is equal to d_1 and its external diameter is equal to the diameter d_2 of the core of the fiber. The refraction index n_2 of the glass that forms part 2 is smaller than n_1.

Finally, the optical fiber comprises a tubular cover 3, with external diameter d_3, that immediately surrounds part 2 of the core: Its internal diameter is thus d_2. The cover 3 can be made either of a glass or, as represented, a transparent plastic such as a silicon resin. The material that forms the cover 3 has a refraction index n_3 which is smaller that n_2.

The in the figure represented fiber can transmit in the core of diameter d_2 multimode optical radiation with an average wavelength L. Hereto the diameter d_2 must be chosen in such a way that the relation:

$$\frac{d_2}{2L} > 0.383\left(n_2^2 - n_3^2\right)^{-\frac{1}{2}} \qquad (1),$$

is satisfied.

As an indication, one could choose, for example:

d_2 = 55 microns

L = 0.830 microns

$n_3 = 1.45$

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and, $d_3 = 140$ microns.

One will notice that inequality 1 is written using n_2 for the refraction index of the core while the core is composed of two parts with indices n_1 and n_2, respectively. In fact, this approximation is valid because the section of the first part 1 is always small with respect to the total section of the core and the refraction index of this first part is very close to that of the second part.

As an example, one has:
$d_1 = 5$ microns
$n_1 = 1.51$.

The in the figure represented optical fiber can also transmit monomode optical radiation, with a wavelength approximately equal to L, when it does not transmit the multimode radiation.

The monomode radiation is thus transmitted in the first part 1, with a smaller diameter, of the core of the fiber. The value of the diameter d_1 of the first part 1 of the core must be sufficiently small so that the following inequality:

$$\frac{d_1}{2L} < 0.383 \; ^{b} \; n_1^2 @ n_2^2 \; ^{c@_2} \qquad (2),$$

which is nothing but the well-known condition for the transmission of monomode radiation, is satisfied.

The fiber described in the above has an external diameter that is much larger than the external diameter and this is strictly necessary in order to ensure transmission of monomode radiation. This relatively large diameter of the fiber is in reality an advantage because it facilitates handling and makes it possible to avoid breaking.

Moreover, part 2 of the fiber, which behaves as a cover when operating in the monomode regime, must be made from glass with a low attenuation in order to ensure good functioning in the multimode regime. In the monomode regime, the low attenuation of this second part 2 allows a significant reduction of the optical losses which one generally observes in the covers of optical fibers that transmit monomode radiation.

The optical fiber according to the invention can be obtained by pulling a warm optical blank if the cover 3 is made from glass. The optical blank can be realized by utilizing the known vapor deposit method or by the introduction of a bar in a tube that is itself located in the internal volume of another concentric tube.

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A fiber according to the invention can be applied to the transmission of information using multimode optical radiation. For this, one directs the radiation of a source with low coherence to the parts 1 and 2 of an end section of the fiber.

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As a result, the same fiber according to the invention can be used initially in a transmission device for information using multimode radiation and later this multimode device could be transformed into a monomode device by changing the radiation source, but without changing the fiber itself.

Of course, the present invention is not at all limited to the realization modes described and represented, which were only given as indications of examples. In particular, one can, without leaving the framework of the invention, change certain arrangements and replace certain means with equivalent means.

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- a first coaxial cylindrical part with refraction index n_1.
- and a second coaxial tubular part that immediately surrounds the first part, while this second part has a refraction index n_2 that is lower than n_1 but larger than n_3,

the value of the diameter of the said first part is sufficiently low so that the optical fiber is capable of transmitting in the first part monomode optical radiation, with a wavelength approximately equal to L, when the optical multimode radiation is not transmitted.

2. Optical fiber according to claim 1, characterized by that the cover consists of a transparent plastic.

3. Optical fiber according to claim 1, characterized by that the cover consists of a glass.